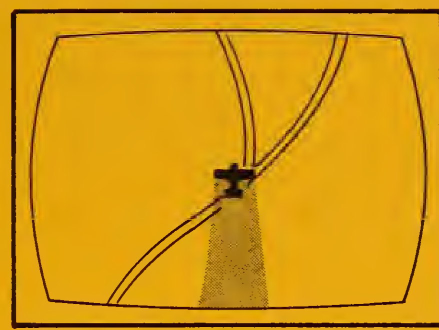
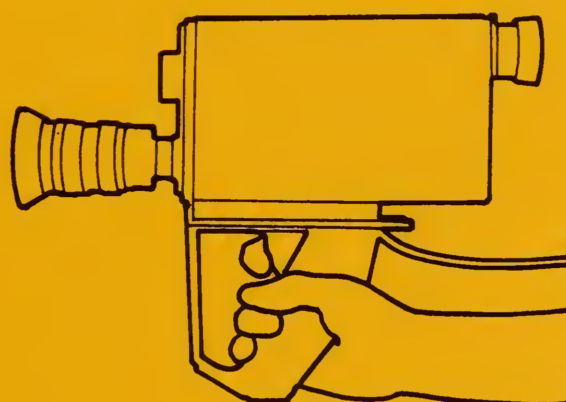


Spray Aircraft Tracking/Guidance System: A Concept

ED&T 2354
SPRAY BLOCK MARKING AND TRACKING SYSTEMS



MAY 1974

U.S. Department of Agriculture
Forest Service
Equipment Development Center
Missoula, Montana

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PROJECT RECORD

SPRAY AIRCRAFT TRACKING/GUIDANCE SYSTEM: A CONCEPT

ED&T 2354

SPRAY BLOCK MARKING AND TRACKING SYSTEMS

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May 1974

USDA FOREST SERVICE
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CONTENTS

INTRODUCTION

In aerial spraying, the prime objective in disseminating the material is to obtain uniform coverage of the target area with the desired dosage. In general, this is accomplished by swathing, a swath being the width of desired coverage on the target produced by one pass of the equipment. Each aircraft generally has a well-defined or accepted swath width and it is up to the pilot to assure that each flight path is so spaced that no skips and/or oversprays exist between swaths. Skips reduce the effectiveness of the application; oversprays waste material and both in the final analysis are costly.

Maintaining this spacing in rugged, forested terrain is a formidable task. Generally the flight path is a zigzag type course rather than a straight line. This is caused by the need to fly relatively close to the tops of the trees, which in turn requires flying to the shape or contour of the terrain. Thus, the pilot must remember where each turn was made on the previous flight, hopefully by remembering some terrain features from that flight--of which there were probably many--and from these he must obtain the proper spacing. Also, at the same time he must pick up new terrain guiding points to be remembered and used as guides for the next swath. Therefore, the accuracy of the application depends solely on the pilot; his experience and familiarity with the terrain all contribute to the accuracy of the application. However, even the most experienced and adept pilot cannot remember and find all these guiding points and some type tracking/guidance system is necessary to assist the pilot if uniform application is to be achieved.

INVESTIGATION OF EXISTING SYSTEMS

The following navigation systems and equipment were investigated for possible use as a tracking/guidance system for aircraft spraying in mountainous terrain.

Decca Survey Systems, Inc.

Manufactures aircraft guidance systems using the Decca navigator. The Decca navigator is a hyperbolic radio navigation system operated in conjunction with ground-based transmitters. An aircraft equipped with special receiver can interpret the transmitted signal and through phase relationship determine its position.

With the transmitters properly located, an area above a spray block would be covered by a series of equally spaced hyperbolic lines. The spray plane could be guided along one or any of these lines using the Decca navigator system.

In mountainous terrain, aerial spraying is seldom done in lines created without relationship to the terrain. Instead it would be a zigzag course contouring the terrain. Thus, this system would appear to have little application except for large acreages in flat terrain where spraying could be done in straight lines generated by the Decca navigator.

Actual accuracy of the system is unknown. On projects where this system has been used, swaths of several thousand feet have been obtained by flying aircraft in echelon. Thus, with real wide swath widths, a small error of 50 to 75 feet in spacing between consecutive swaths accounts for only

a small portion of the total spray area. However, in mountainous terrain with smaller aircraft and smaller swath widths, this error consumes a considerable portion of the total spray area.

In general, this system would be more suited for guiding spray aircraft when the acreages are large and on flat terrain. Also, larger spray aircraft would have to be used to provide for a copilot/navigator to read the instrumentation. As the transmitted radio wave is an electromagnetic wave it is subject to normal atmospheric interference which could be a problem.

Litton Aero Products Co.

They are adapting their commercial inertial navigation system (INS) into a guidance system for agricultural spray aircraft. The system basically consists of gyroscope, accelerometers, control display and computer, all mounted in the aircraft. Ground-based distance measuring equipment (DME) is used for position updating. The system is still in the development stage with a limited number of field tests.

With this system, drift of the gyroscope creates considerable internal error that can only be corrected by realighment through use of ground-based DME's. The number of turns or maneuvers accomplished by the spray aircraft also affects the drift of the gyroscope. Thus, good accuracy could be predicted on relatively straight flight paths. However, in mountainous terrain where a zigzag type course is necessary, considerable error would be expected between swaths.

Recent inquiries revealed that further development of this system has been given low priority by the company.

Infrared Scanner

The Forest Service has a forest fire (heat) detection system which is essentially made up of an infrared (IR) scanner and recorder. The recorder produces a continuous chart of the IR images of the objects flown over and detected by the infrared scanner.

Hopefully, this system could be flown over a spray area and detect the heat from the spray aircraft engine, thus positioning it with respect to the terrain. However, it was found that the width of coverage perpendicular to the flight path, obtained by one scan, was only a matter of several feet (depending on altitude, speed and optics). This would require the scanner be flown directly above the spray plane at all times in order to keep the spray plane within the field of the scanner. This task, for practical purposes, is virtually impossible. Also, it is questionable whether enough thermal variations would exist in the background (trees) to show on the imagery and be usable as a reference for guidance purposes. For these reasons, investigation of the infrared scanner as a guidance system was discontinued.

Theodolite

An optical instrument that can measure angles both in the horizontal and vertical plane. The equipment can be automated by using electronics for taking the readings and for calculations. This automated equipment would be necessary for a real time tracking/guidance system.

This equipment could be used to track and guide a spray aircraft, but is impractical from an operation standpoint for these reasons:

1. Three instruments are necessary, each at a different location, in order to establish the position of the spray aircraft.

2. The spray aircraft would have to be visible to the three instruments at all times throughout the entire spray area. This would be extremely difficult in mountainous terrain.

3. The relative position of each instrument must be established. This may be accomplished by either locating each instrument so that a direct line of sight is established between all instruments or locating each instrument by ground survey.

4. The elevation of each instrument with respect to a known datum plane must be established.

5. A communications network is necessary for the transmittal of data from each instrument to the computer.

Therefore, this equipment, due to its complexity, is more suited for fixed installations rather than mobile use.

Transponder

A radio transmitter/receiver used as a homing device or as distance measuring equipment (DME). An aircraft equipped with the proper receiver can determine the direction and distance to the transponder.

This system would not work as a guidance system for spray aircraft because even though the aircraft can fly directly to the transponder, it does not control the flight path taken. The incoming aircraft is theoretically flying inside a cone which has its apex at the transponder. The aircraft could be flying anywhere within the diameter of the cone and still be on course, thus leading to considerable error. Also, considerable logistics and operational problems would be encountered in placing transponders along the flight path at each turning point and in moving them between flights.

Photography (Multispectral detection)

If the spray aircraft pilot could see the spray from the previous flight path, it could be used as a guide for the present flight path. Hopefully this could be accomplished by using a dye to identify the spray and then use special equipment and techniques to detect the dyed spray. The problem would be to determine if the dyed spray could be detected and how long it would remain detectable.

Tests were conducted during the 1973 pine butterfly field experiment on the Bitterroot NF to see if this method was practical. Oil red dye (I. E. du Pont de Nemours & Co.) and Rhodamine B Extra Base fluorescent dye (General Analine and Film Corp.) were used to dye the spray and a multiband camera obtained from Forest Pest Management, Southeastern Area S&PF was used to photograph the spray. These photographs were evaluated using multispectral color enhancement equipment available at the University of Montana. Results indicated that the dyed spray was easily detectable but quickly dissipated to such low concentrations as to be undetectable from swath to swath even at application rates of 2 gallons per acre.

PROPOSED CONCEPTS

Many navigation systems and equipment that could be used as a guidance system for spray aircraft were investigated. None were found that could guide a spray plane over rugged, forested terrain.

In general, the commercial systems were electromechanical in nature with very little human interface and thus very expensive. They are more suited for very large acreages on gentle terrain where the flight paths are long and straight and several aircraft can fly in echelon. Also, they require a copilot/navigator to read the instrumentation and thus are suited only for larger type aircraft.

Of the methods and devices investigated, all were found to be impractical.

However, the investigation did lead to the possibility of using television. The most promising concept was that of using a closed circuit television (CC-TV) system as outlined in concepts A and B. The major components of a CC-TV system consist of a video camera, video-tape recorder, and monitor, as shown in figure 1.

Concept A

In applications where the spraying is accomplished by back and forth swathing, each flight path would be represented by a line and the distance between lines would be maintained by adjusting the flight path (line) as necessary.

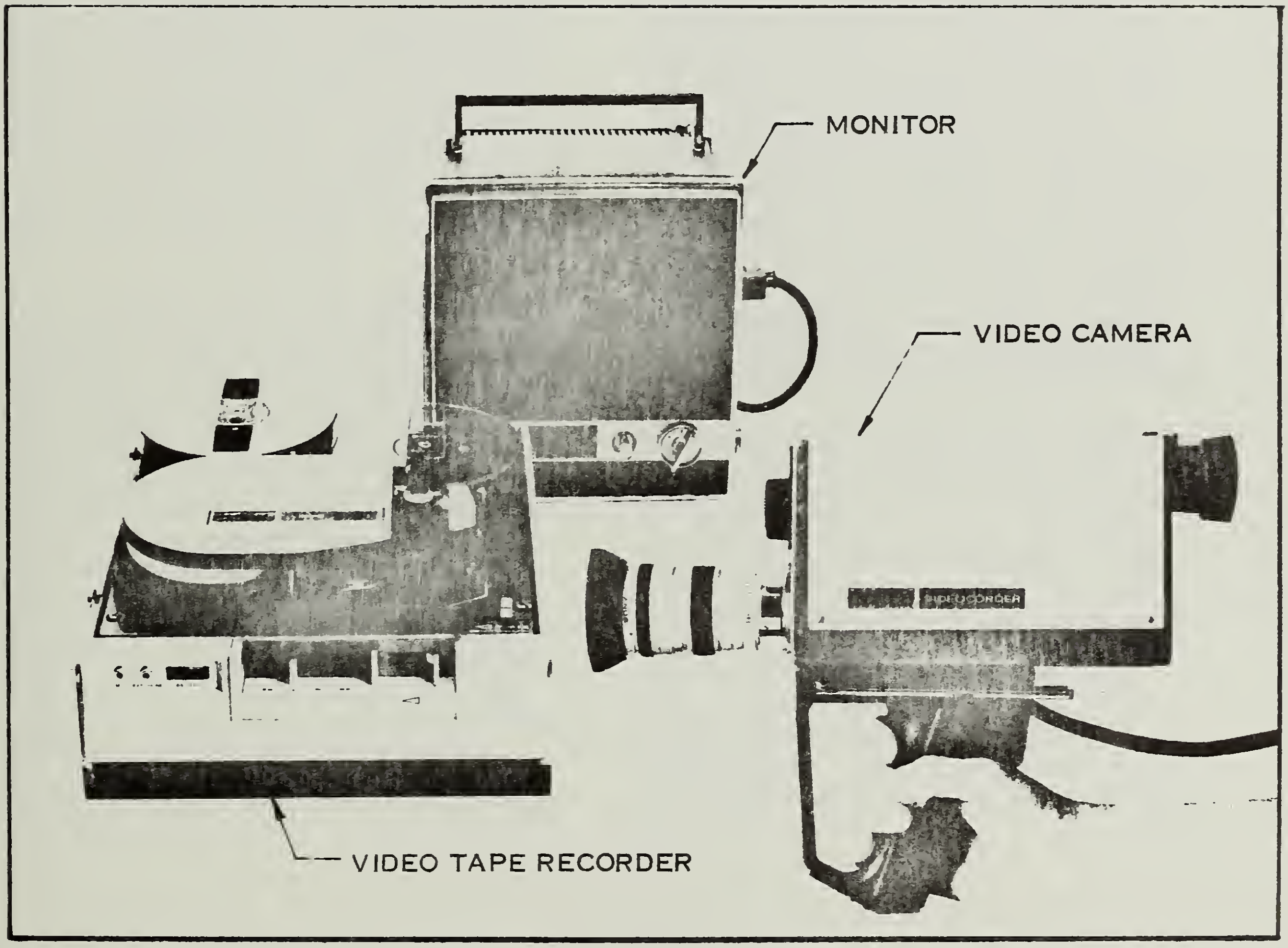

Figure 1.--Major components of a closed circuit television systems.

A CC-TV system (tracking CC-TV system) would be placed in a stationary position above the spray block (fig. 2). The image of the entire spray block would be displayed on monitor No. 1. The image of the helicopter as it sprayed the block would also appear on the monitor, allowing the controller to trace its path on a transparent overlay placed over the monitor screen. Each path (swath) of the spray helicopter would then be represented by a line on the overlay and the spacing between consecutive lines would represent the swath width. The controller, through normal radio communication, would inform the spray pilot of what actions to take in order to maintain the desired swath width.

A helicopter (photo helicopter) would be used to place the tracking CC-TV system in a stationary position above the spray block. Stationary positioning is necessary in order to maintain the relationship between the photo helicopter and the spray block. To assist in this positioning, a second CC-TV system (positioning CC-TV system) would be used in conjunction with ground aiming points such as a prominent terrain feature or a target. The positioning CC-TV system monitor (monitor No. 2) would be used by the pilot to maintain the position of the photo helicopter above the aiming point. Video camera No. 2 would be fixed to the helicopter structure and would require the pilot to maintain the helicopter in a hovering (stationary) position in order to keep the aiming point in the center of monitor No. 2. Altitude would be maintained by use of the altimeter.

The tracking CC-TV camera (camera No. 1) will be hand held in order to counteract maneuvering of the helicopter during hovering and will have two aiming points, viewed through a telescope. The primary aiming point will be the center of the block and the secondary aiming point will be offset from the primary. The primary will be used to keep the center of the plot always the center of the monitor screen. The secondary will be used to reduce rotation of the camera which would cause the lines on the overlay to converge/diverge, destroying the relationship between consecutive lines.

At present this concept would apply to small size spray blocks that would fit into the field of view of the camera, of about 50 acres or less in size. This size can be varied some by the focal length of the camera lens and altitude. However, by use of several photo ships, operating in relays, and special techniques such as oblique camera angles the size of the block could theoretically be increased indefinitely. This concept would work with either a fixed-wing or helicopter type spray craft.

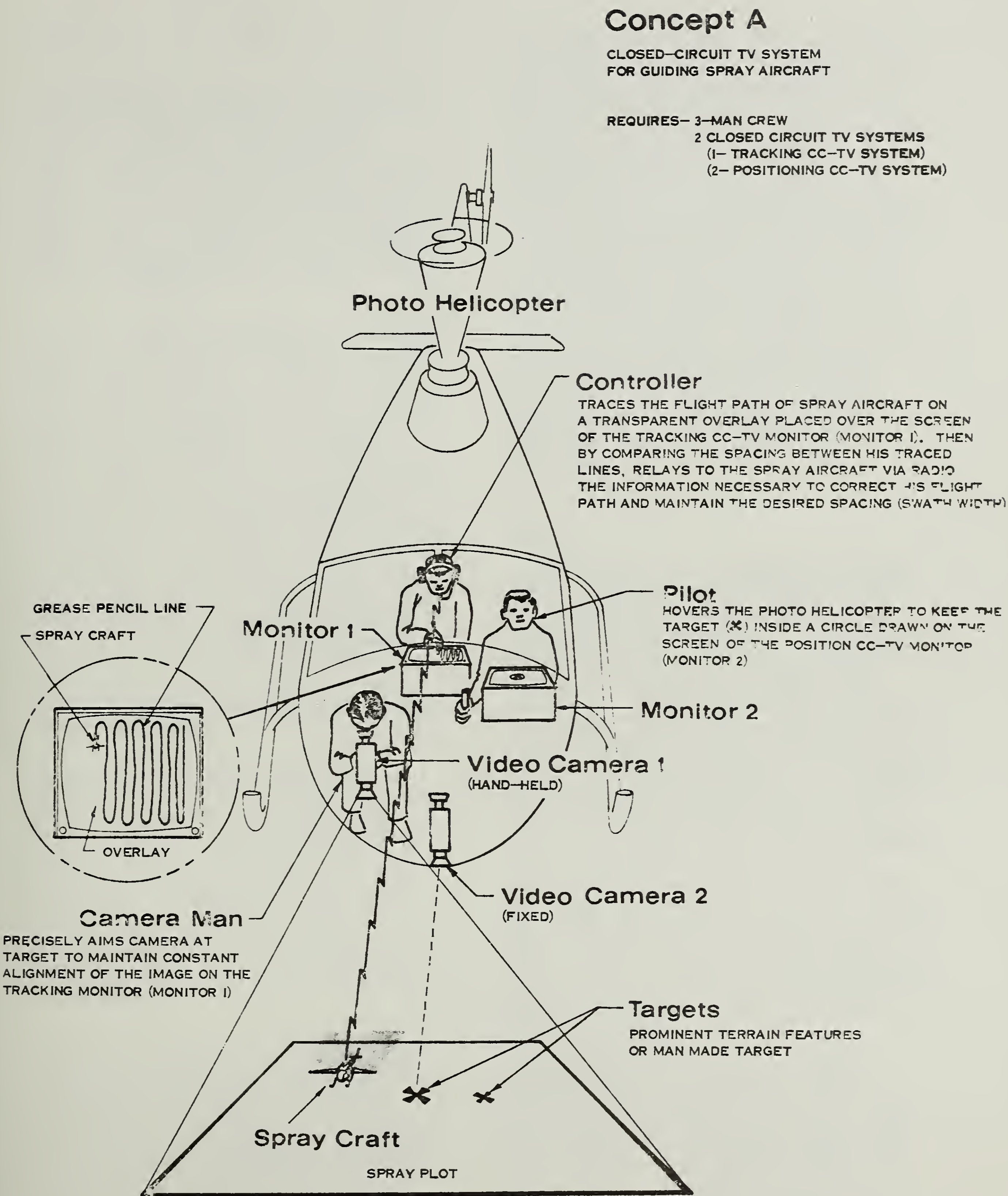

Figure 2.--Concept for guiding spray aircraft.

Concept B

In applications where the spraying is accomplished by swaths, all flown in the same direction, the spacing (swath width) between consecutive swaths would be maintained by comparing the position of the spray plane with respect to the terrain, on the present flight path, to that of the previous pass, and adjusting the present flight path as necessary.

A CC-TV system (tracking CC-TV system) would be placed vertically above the spray plane (fig. 3). Images of the spray plane and the terrain it is flying over would appear on the tracking monitor and represent the present flight path. A replay of the previous flight path would be simultaneously displayed on an adjacent monitor and would be used as the base for comparing the present flight path. A controller would compare the relationship of the spray plane with the terrain from the present pass with that from the previous pass. Then through radio communication with the spray pilot, give instructions on how to maintain the desired distance (swath width) between flight paths based on this comparison.

A fixed-wing airplane (photo plane) would be used to fly the tracking CC-TV system above the spray plane. The tracking camera would be hand held in order to keep the spray plane in the most desirable field of view for the controller. The images on the two monitors would be kept in phase (same terrain appearing on each monitor simultaneously) by existing controls on the equipment.

To assist in keeping the photo plane in a near vertical position above the spray plane, a second CC-TV system (position CC-TV system) would be used. Near vertical positioning of the photo plane above the spray plane is desirable, in order to keep the relationship of the terrain and spray plane relative to the photo plane the same swath after swath for best controller interpolation and pilot control. The position system camera would be attached to the photo plane structure at such an attitude that when the photo plane was directly above the spray plane, the spray plane image would appear in the center of the position system monitor. This monitor would be located for continuous viewing by the pilot and would have a small circle placed on its screen, which the pilot should always keep the image of the spray plane within. Speeds, altitudes, and rates of descent for the photo plane and the spray plane will be synchronized using normal cockpit instruments. This concept could be used with either an airplane or helicopter.

TESTS

Limited tests were conducted to check the operational capabilities of the CC-TV system and develop techniques as required by each concept. Information gained from these tests was used to modify or change the concepts when necessary. These tests were run using a simulated spray airplane and the actual spray helicopter during the pine butterfly field experiment. At no time was an attempt made to try to actually guide the spray aircraft due to the lack of equipment and proper techniques.

Using a simulated spraying operation, the resolving power of the CC-TV system was found sufficient to distinguish the image of the spray aircraft, trees and other terrain features required by both concepts. At an altitude of 3,000 feet above ground level (AGL) the CC-TV system resolution was sufficient to clearly show the image of a white colored Cessna 185 airplane used to simulate the spray plane. Also, there were no difficulties in distinguishing the outlines of individual trees and other terrain features. Several runs were made at speeds of 150 MPH and 3,000 feet AGL and the camera field of view (approximately 1,700 feet by

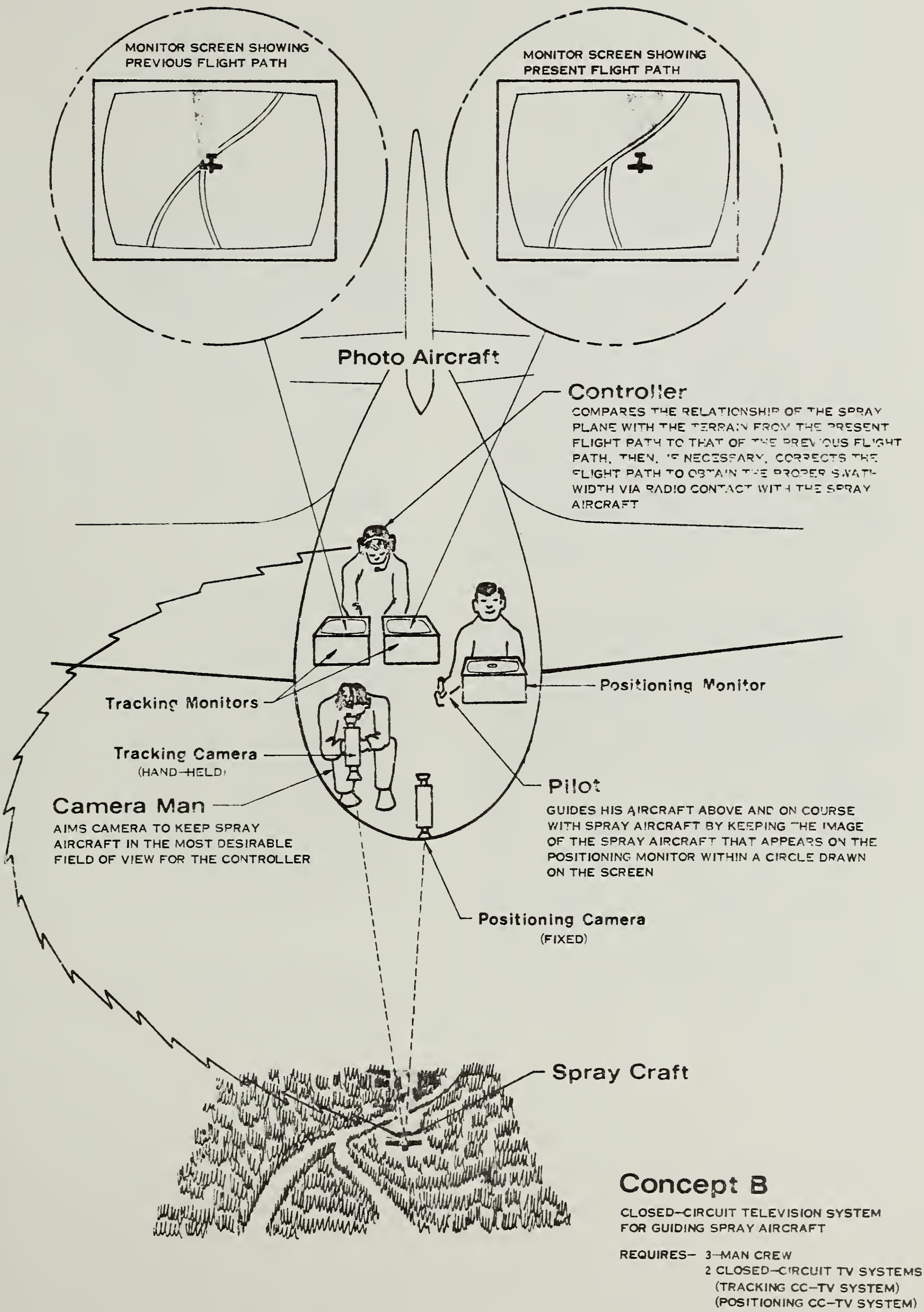

Figure 3.--Concept for guiding spray aircraft.

1,250 feet with a 12.5 mm F.L. lens) was judged sufficient to be able to guide a spray plane as outlined in concept B. These tests indicated the photo plane should fly as near vertical above the spray plane as possible for best interpretation of the field of view. Therefore, concept B was modified and a positioning CC-TV system was added to assist the photo plane pilot in maintaining this relationship between the spray plane and photo plane. This positioning CC-TV system was not evaluated during these tests due to insufficient time and equipment.

During the pine butterfly field experiment in the Bitterroot National Forest, several spray blocks, 40 acres in size, were used to evaluate the ability of the pilot to hover the photo helicopter over a spot as required by concept A. Results indicated the helicopter tended to drift considerably due to the distance to any ground references and some method would have to be devised to assist the pilot in hovering. Thus, concept A was modified and a positioning CC-TV system added to the original concept to assist the pilot in hovering. The positioning CC-TV system was not evaluated due to the lack of equipment.

The CC-TV system recorded the spray swaths from approximately 2,000 feet AGL and the spray helicopter, although harder to see due to its open lattice type framework than the Cessna 185, was distinguishable. Also, when the video tape was played, several double swaths (oversprays) and skips were noted (fig. 4), even though the spray pilot was given a thorough preflight briefing. This briefing included an aerial reconnaissance of each spray block and in some cases even simulated spray runs were made over the blocks. Personnel from the Dugway Proving Ground, using a theodolite, also determined the position of the spray helicopter once during each pass and this data (fig. 5) also shows several oversprays and skips.

Figure 4 shows the apparent flight paths of the spray helicopter (Bear Creek Plot) obtained from the video tape during post mortem analysis. Flight paths (2, 3, 4, 5, 6) (18, 19, 20) and (21, 22) would represent areas of overspray, while the area between paths (7, 8) (15, 16) and (16, 17) would be skips. In general, the positions of the spray helicopter shown in figure 5 (Smith Creek Plot) indicate the same type oversprays and skips. Swath numbers (8, 10) and (19, 21) would represent an overspray, while numbers (5, 3) and (6, 4) are out of sequence. This all points to the need for some type guidance system for uniform coverage of the spray area.

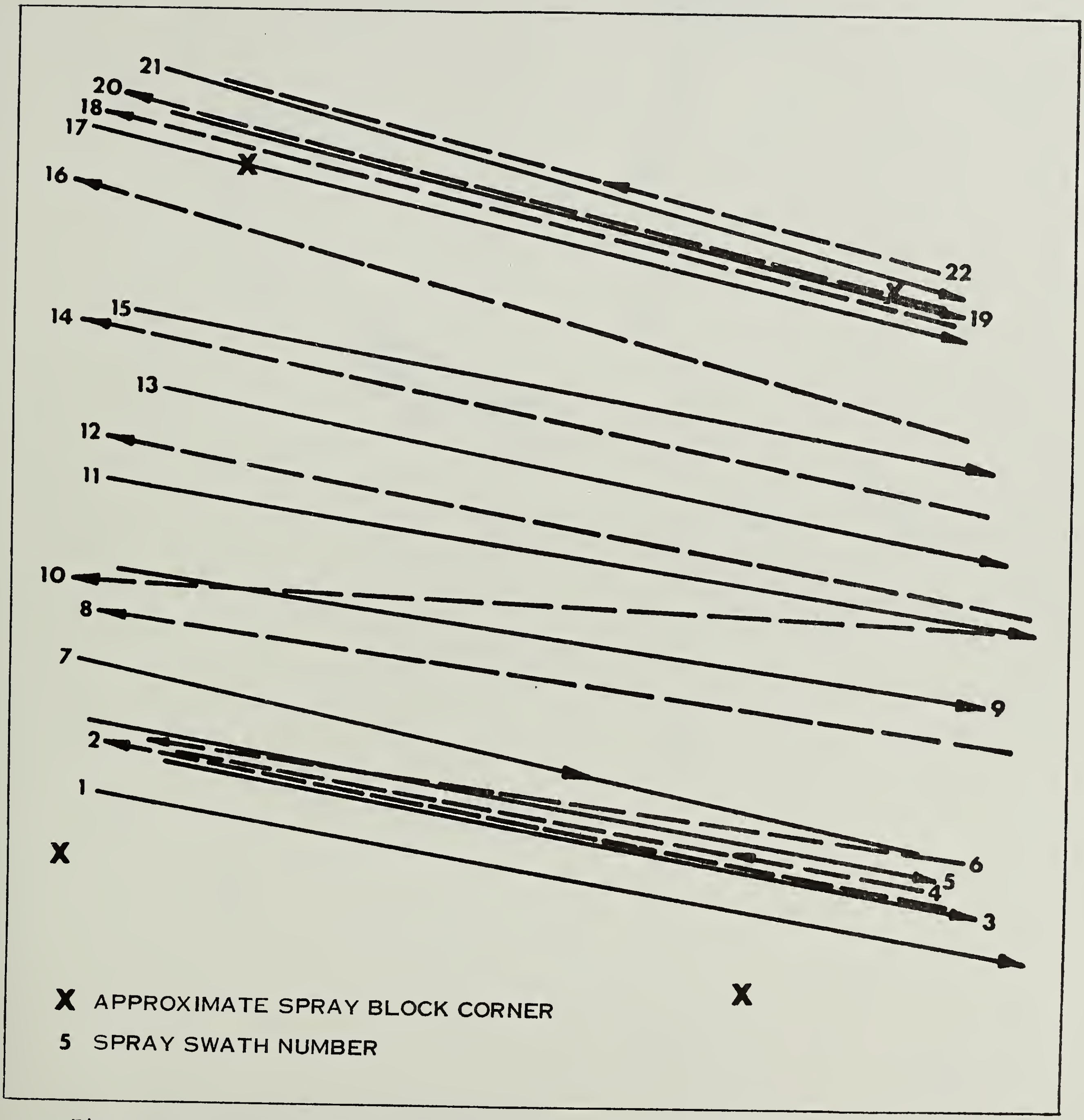

Figure 4.--Apparent flight paths of spray helicopter over the Bear Creek spray block (data obtained from a videotape).

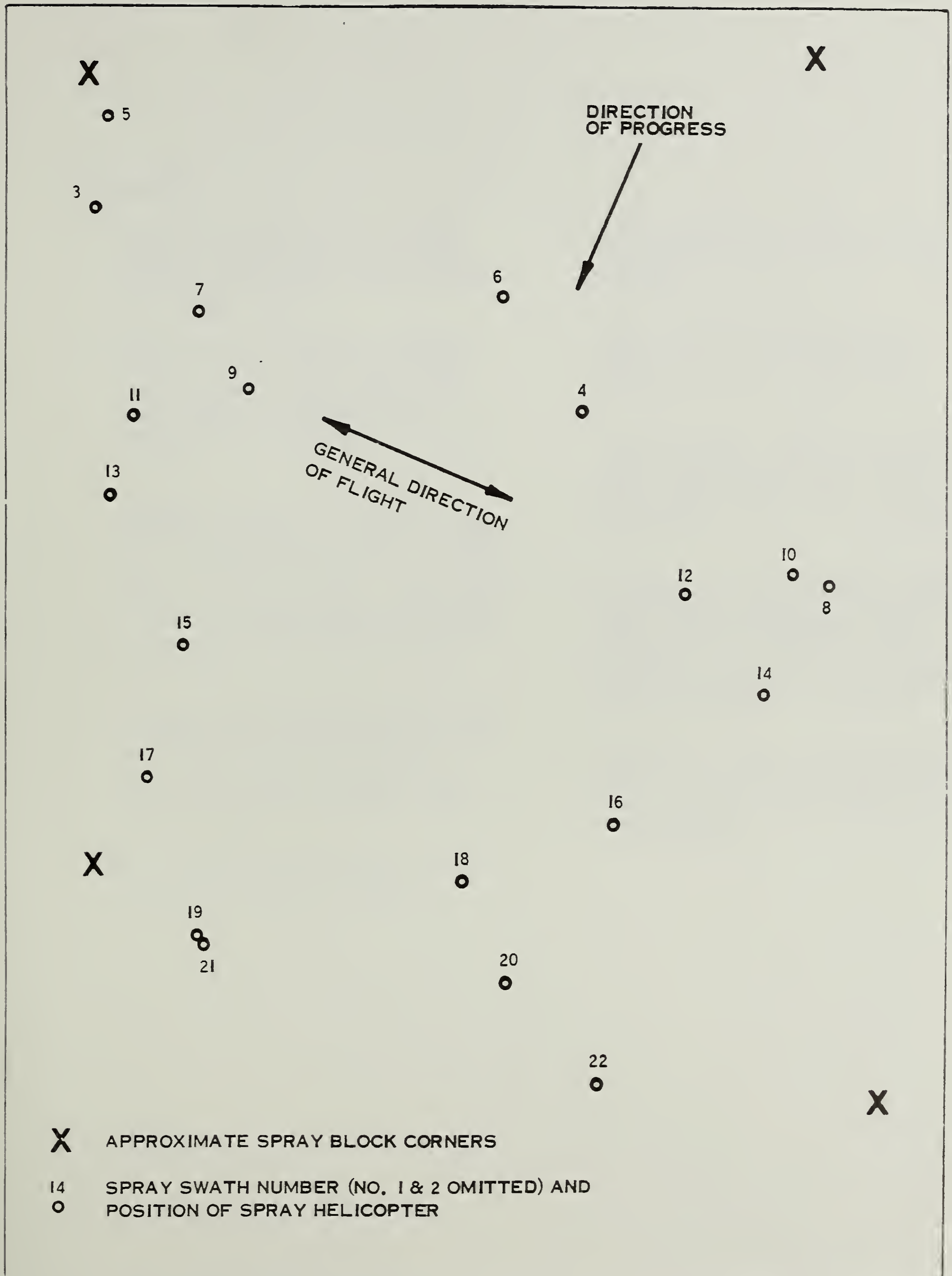

Figure 5.--Helicopter position located once during each swath by Theodolites (Smith Creek spray block).

CONCLUSIONS

1. None of the commercial guidance systems investigated were found capable of guiding a spray aircraft over rugged terrain.

2. Neither of the proposed concepts will produce a precise guidance system as both depend upon human techniques and judgment for accuracy of the tracking/guidance system:

   Concept A requires the camera operator to hold the camera steady while aiming accurately at a target and also preventing it from rotating about its line of sight. The controller must judge the swath width by comparing the spacing between two lines.

   Concept B requires the controller to compare the relationship of the spray plane and terrain on one monitor to that on another and judge the distance (swath width) between them.

   Both concepts have potential over procedures currently in use.

3. Positioning of the photo aircraft is crucial to the success of both concepts.

4. Both concepts would utilize commercially available CC-TV systems which are relatively inexpensive.

5. The video tape from the system would provide a record of each spray swath which would allow a post mortem analysis of the spray operation.

6. Guidance of the spray craft would be achieved through normal radio communication equipment, thus eliminating the need for special equipment installation, modification, or addition of a copilot to the spray craft.

7. The photo aircraft must have sufficient capacity to accommodate the camera operator, controller, and the equipment.

RECOMMENDATIONS

Continue development, testing and evaluation of these concepts in order to determine their practicability as a tracking/guidance system. Cost of such a program would be approximately $25,000 and include the following:

1. Test the proposed system for positioning the photo plane over the spray plane/spray block.

2. Determine the ability of the controller and camera operator to perform their duties as required.

3. Evaluate completed system on a spray project (field experiment).

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